TILAPIA AQUACULTURE IN MEXICO

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ABSTRACT

Mexico produces more tilapia than any other country in the Americas, 94,279 t in 1996. Tilapia are cultured under extensive and intensive methods and are captured from reservoirs stocked with fingerlings. There are highly developed internal markets and few fish are exported. Culture methods have become more intensive in recent years, with improved feeds, development of cage and raceway culture, genetic manipulations and more skilled producers. The government has begun a project to develop 3 tilapia parks. These parks will be research, education and demonstration sites as well as major production locations. As additional technology is applied, Mexico's tilapia production will expand. Mexico, with its large domestic demand, proximity to US markets, and enormous water resources for tilapia culture, will soon be a major factor in the international trade in tilapia.

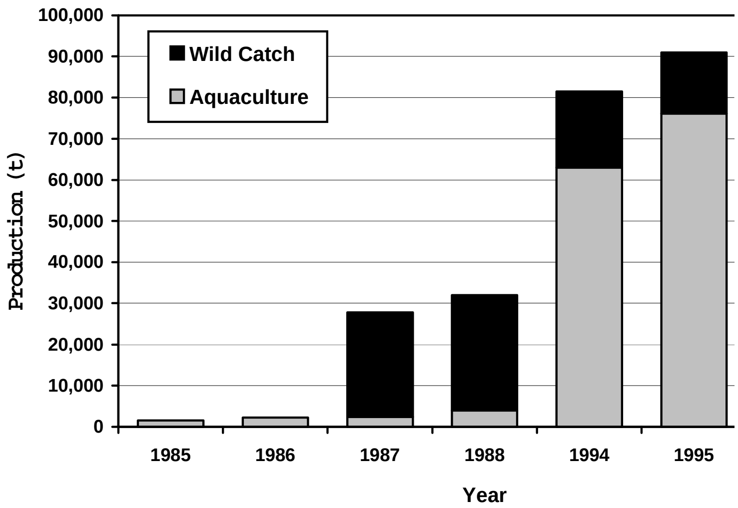
INTRODUCTION

During the 1990s Mexico has become one of the world's major producers and consumers of tilapia. In 1987, national production was 27,765 t of tilapia, and by 1996 Mexico produced 94,279 t (Figure 1). The amount of tilapia derived from aquaculture operations in 1996 was 79,154 t. Many fish reported for aquaculture were derived from fingerlings released into reservoirs in ranching operations. Tilapia represents the third largest seafood product (by weight) of Mexico, after sardines and tuna, and the 4th most valuable, after shrimp, tuna, and octopus (Table 1). Virtually all production was consumed domestically. The industry is widely diversified in terms of geography, with production reported for all but 4 states, and methods of production, ranging from extensive stocking and recapture to super-intensive controlled environment culture. Aquaculture of tilapia may be a fairly recent phenomenon but fish farming is not new to Mexico. In pre-Hispanic times fish were maintained for "ritual and religious" purposes (Aguilera Hernández and Noriega Curtis 1991a). In 1883 Esteban Cházari wrote the first text on fish culture in Mexico (*Piscicultura en Agua Dulce*). Many species are now raised domestically and there is a well developed aquaculture infrastructure.

Several tilapia species were introduced to Mexico in the 1960s and 1970s. *O. mossambicus* and *O. aureus* were first introduced in 1964 (Pullin et al. 1997), *O. niloticus* and *O. urolepis hornorum* in 1978 (Pullin et al. 1997), and *Tilapia zillii* and at least one red hybrid sometime in between. Several additional populations of each of these species have been brought into Mexico. Introductions are the result of privately sponsored imports as well as state and federal fisheries programs. Tilapia are now found in every state in Mexico and are established in the wild across much of the country. Tilapia are widely recognized as an important food fish.

In the early years after introduction, tilapia were referred to as mojarra or mojarra africana. This was especially true of the *O. mossambicus*. The name mojarra is still encountered in some instances, but tilapia is now recognized in much of the country as the common name. *O. mossambicus* are no longer the major culture species of tilapia in Mexico. *O. aureus* are the most common tilapia in the south of the country and in reservoir fisheries. *O. niloticus* and red strains are the most widely cultured species in intensive operations, which occur mainly in the northern states. Much of the public is aware of tilapia and the fish can be found in grocery stores in many regions. The fish are usually sold fresh whole on ice, but some stores are now beginning to sell them headed and gutted and on rare occasions as

Figure 1. Tilapia production in Mexico.



packaged fresh fillets. The Mexican government as well as most state governments are committed to supporting the growth of aquaculture as a replacement for over-fished wild stocks and as a technological innovation to make rural agriculture more productive and lucrative. With the abundant water resources and proximity to US markets, further growth of small and industrial scale tilapia culture is anticipated in Mexico.

DISTRIBUTION

Mexico is a large country with extensive freshwater and marine resources (Figure 2). Veracruz was the leading tilapia producer state with 16,804 t (Table 2). The values in Table 2 represent only the production from aquaculture operations. The rest of the national production comes from capture fisheries in reservoirs. The national tilapia aquaculture figures sometimes include those captured fish because the lakes are stocked with fry and fingerlings from state and federal hatcheries. It is not known what the contribution of the hatchery stocks are to the overall catch. Some sources claim that stocked fish are critical while others feel that the established populations in the reservoirs are providing all the recruitment needed. This discrepancy shows up in the FAO statistics, which do not recognize those fish as aquaculture products.

Table 1. Production and value of fishery products of Mexico, 1996. Derived from SEMARNAP, Fisheries Statistics (1996).

Product	Weight (t)	Value (pesos x 000)
Sardines	344,403	115,927
Tunas	129,342	1,171,839
Tilapias	94,279	393,038
Shrimp	61,235	2,254,636
Octopus	29,450	470,317

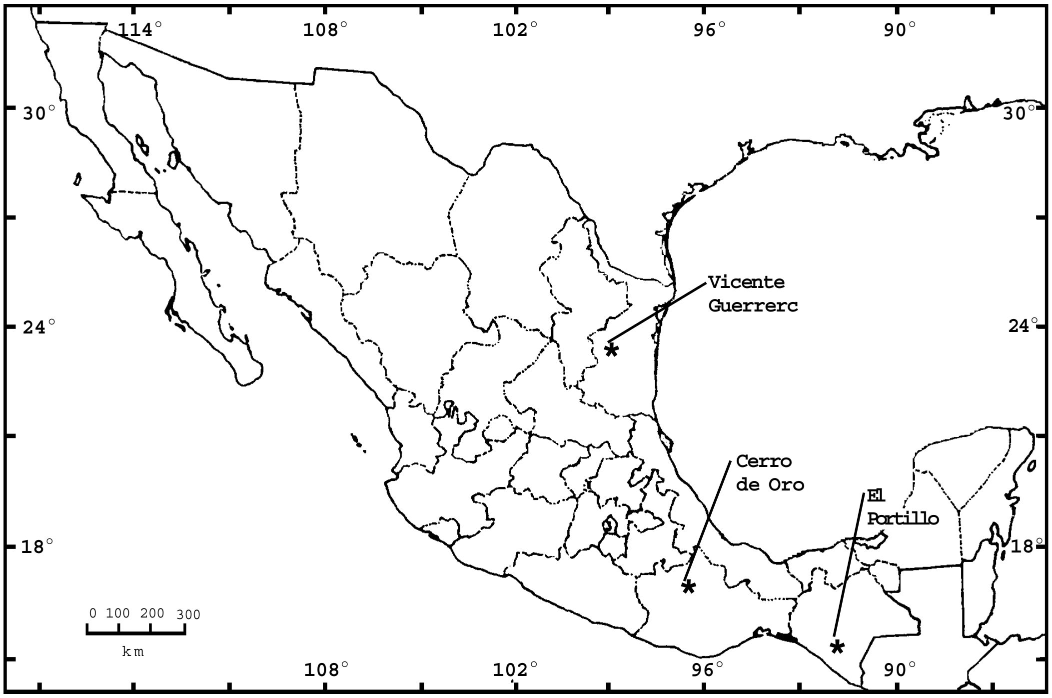
Types of Culture

Small Pond Culture–*Cultivo en Estanques Rusticos*

The earliest form of tilapia culture in Mexico was conducted in small ponds under extensive culture conditions. Early introductions were related to state programs which were devoted to providing fry and fingerlings to subsistence farmers who needed the fish production to increase protein intake in their diets. There were additional projects, often supported by missionary and religious organizations, that supported small hatcheries supplying juvenile fish to *ejidos* (communal farms), social cooperatives, orphanages and church groups.

Extensive production in small ponds is still practiced widely throughout the country. State and Federal hatcheries often provide fry to individual farmers and to cooperative groups at subsidized prices. Hatcheries produce young fish and either make them available for pick up by producers, or, in some cases, deliver them to the farmers. Fish are sometimes reared only on the productivity of the

Figure 2. Tilapia production areas in Mexico.



pond ecosystem. In other cases the farmer fertilizes the pond with organic or chemical fertilizers. There are several publications available (Morales 1974; Porras Diaz 1990; Aguilera Hernández and Noriega Curtis 1991a,b) that detail the procedures that are followed.

Cultivation of tilapia in rice fields and in conjunction with chicken and pig production has been tested at the Granja de Policultivo de Tezontepec in Hidalgo (Martinez Torres and Abrego Ayala 1991). Neither of these methods is widespread yet in Mexico, but there is considerable potential. One form of integration that has become common is production of tilapia in irrigation water. Small ponds are often built to store irrigation water on farm and can be used for tilapia production. A variation is to rear fish in the drainage water from an irrigated field. This practice is less appealing as the fields may leach fertilizers and pesticides that could accumulate in the fish.

Another type of small pond culture that is practiced in the southern state of Oaxaca is called the *microcuenca*, or small watershed system. A *microcuenca* is a small reservoir that forms when a dam is built in an eroded watershed. The primary reason for the reservoir is to control downstream flooding and to capture sediments that otherwise would flow downstream. The reservoir can be stocked with tilapia or other fish, normally from a state hatchery. The fish are fed a diet based on local ingredients or the reservoir may receive organic fertilizers to increase productivity. The stored water is then used for local irrigation of grains, beans or vegetables. In some cases the water with fish effluent is used to irrigate small tree nurseries. The trees are used to reforest areas in the upper watershed. The pond sediments can also be removed for use on crops.

Stocking in Reservoirs–*Presas*

A practice that contributes significantly to tilapia production throughout Mexico is stocking and harvest from reservoirs. In the 1960s and 70s a number of major dams were built creating multi-purpose reservoirs. In addition to providing electrical power, irrigation water, potable water and flood control, the reservoirs proved to be valuable as inland fisheries resources. There was spotty documentation of the native fish fauna in most of the areas inundated by the dams. Rather than wait to see if any of the native fish survived, tilapia were introduced in an effort to quickly improve the fishery of the new reservoirs. Several of the lakes even had hatcheries built as a part of the overall construction plan.

Table 2. 1996 Tilapia aquaculture production in Mexico. Derived from SEMARNAP, Fisheries Statistics (1996).

State	Production (t)
Aguacalientes	50
Baja California	-
Baja California Sur	-
Campeche	250
Chiapas	4,055
Chihuahua	124
Coahuila	10
Colima	685
Durango	602
Guanajuato	1,436
Guerrero	2,906
Hidalgo	646
Jalisco	4,128
Mexico	400
Michoacan	15,363
Morelos	1,085
Nayarit	889
Nuevo Leon	56
Oaxaca	588
Puebla	648
Queretaro	223
Quintana Roo	-
San Luis Potosí	237
Sinaloa	4,218
Sonora	1,135
Tabasco	13,213
Tamaulipas	2,657
Tlaxcala	-
Veracruz	16,804
Yucatan	2
Zacatecas	6,744
TOTAL	79,154

These projects were envisioned as "ranching" operations in which hatchery reared juveniles would be stocked in the lake and allowed to grow. Later, resettled families would harvest the fish and consume them directly, sell them locally or market them to the nearest municipality. Of course the tilapia quickly became established in the reservoirs and began reproducing on their own. The harvest of the fish has been quite successful and these reservoirs now provide many of the tilapia available in the markets. Tilapia coming from the reservoirs are usually included in the aquaculture statistics because there are still active stocking programs adding juvenile tilapia. Fishermen report that their yield decreases if stocking is suspended, although there seems to be little if any data to support that claim.

Cage and Pen Culture–*Jaulas and Corrales*

Jaulas are floating cages that do not normally touch the bottom of the body of water in which the cages are situated. *Corrales* are net pens that use staked sides and then allow the bottom net to rest on the bottom or forsake a bottom net altogether. One interesting variation on the corrals is the use of *encierros* (confinements), which consist of wooden structures that enclose portions of a lagoon. Those structures are used to culture tilapia most commonly in the Alvarado lagoon system just south of the city of Veracruz. The *corrales* seem to be losing popularity and are being replaced with floating cages in deeper or flowing water.

Two types of *jaulas* are used in Mexico. One type, commonly utilized by low income social groups or individuals, is constructed out of inexpensive local materials (FONDEPESCA 1981) (Figure 3). The other type used in more intensive production systems incorporate floating docks, custom-made nets and other materials specially made for net pen culture (Figure 4). Cages are important for growers who wish to control reproduction in their systems. Cage culture greatly reduces fertilization and recovery of eggs by the spawners if the eggs fall through the net mesh. Harvest from cages is also less complicated than recovering fish from a larger, open body of water. Most cage operations use floating or slow sinking pelleted feed. Most of the reservoirs where these cages are placed have been filled within the last 20 years and are used for irrigation. Eutrophication of reservoir waters or fouling below the cages has not become an issue. Since tilapia feces often float and break up readily, fouling below cages is not a problem. However, eutrophication may become a problem if irrigators do not take sufficient quantities.

Raceways–*Canales de Flujo Rapido*

The author is not aware of any raceways that were constructed specifically with tilapia culture in mind. One hatchery/demonstration farm near Abasolo, Tamaulipas constructed a series of raceways that were designed for catfish studies but now are stocked with tilapia. The raceways were built in a series of stair steps with 17 reuses of the water (Figure 5). The design was based loosely on a system developed for catfish by Leo Ray of Idaho. The vertical drops are sufficient to replace oxygen in the raceways, but there is no mechanism to remove ammonia from the water. That metabolite accumulates in the water and reduces growth of the tilapia. The managers of the demonstration farm leave sections of raceways open to allow for solids settling

Figure 3. Rustic cages in reservoir.

and some natural dissipation of ammonia which allows some production in the lower raceways, but much of the facility is underutilized. When stocked heavily, the raceways were found to be effective for controlling unwanted reproduction and for ease of feeding and harvesting. One of the problems encountered was that the fish had a tendency to congregate near the head of the raceway where the oxygen levels were highest. Any uneaten feed would then be pushed to the opposite end and begin to decay. Another problem was jumping. The tilapia would jump from one raceway to the adjoining raceway, thereby mixing up the inventory. They would also expend considerable time and energy attempting to jump up the waterfall to the higher raceway. A final problem with the raceways was that the sides were convenient for fish eating birds to perch. The actual "Ray design" uses intermediate filtration sections to remove the ammonia. That design was incorporated at the adjacent Desarrollo Piscícola, S.A. (DEPISA) farm.

Figure 4. Array of intensively managed cages in reservoir.

Figure 5. Raceways stocked with tilapia in Tamaulipas.

DEPISA was started in the late 1980s and has changed ownership a couple of times. It was built for catfish production and receives water from the irrigation system fed by the Vicente Guerrero Reservoir. Up to 18,000 gallons/min are diverted through the farm and then returned downstream into the irrigation canal for later use on field crops (Figure 6). DEPISA has 89 raceways and 40 ha of ponds. The raceways are operated in modules with filtration sections between modules. The filter sections maintain water quality by removing ammonia, adding oxygen and settling out any solids that were missed in the quiescent zones at the ends of the raceways. Operations were redirected towards tilapia when US prices for catfish fell and tilapia prices in Mexico and the US stayed relatively constant. The farm also includes a complete processing plant with fresh and frozen capabilities.

Figure 6. Aerial view of DEPSIA farm near Abasolo, Tamaulipas.

Intensive Pond Culture–*Cultivo en Estanques Intensivos*

The intensive flow-through style of pond culture practiced in Taiwan, Colombia and Costa Rica is still rare in Mexico. DEPISA does raise tilapia in ponds as well as raceways (Figure 6). Water diverted from an irrigation system is delivered to the tilapia farm, passes through the ponds and is returned to the canal for irrigation of field crops. These ponds are not stocked as heavily or provided with as much flow as intensive ponds in other parts of the world. There are intensive pond systems devoted to catfish in Durango and trout farms in Morelia. This technology and experience will probably be applied to commercial tilapia production soon. There are several tilapia hatcheries operated by state and federal agencies that have access to large volumes of water and multiple ponds, but none of the government facilities rear large volumes of tilapia for food production. Instead they focus on fry and fingerling production to supply to the social sector.

Intensive Round Tanks–*Cultivo en Tanques Circulares*

Cultivation of tilapia in round tanks in an intensive system is still rare in Mexico. A commercial facility that rears tilapia and catfish operates near the DEPISA farm outside of Abasolo, Tamaulipas. This farm uses a gravity-fed water supply from the Vicente Guerrero irrigation canal. The tanks are drained through a center standpipe and supplemental aeration is provided using oxygen injection. (Figure 7) The farm has an on-site feed mill using an Insta-Pro Extruder. Processing is completed at the farm with freezing and packaging available. The processing plant brings in other freshwater and marine products, as the tilapia production has not reached the capacity of the processing facilities.

The San Patricio Farm, south of Ciudad Juarez in Chihuahua, uses a recirculating system to raise tilapia in a greenhouse complex. Some fish are kept in round tanks with center drains while others are reared in rectangular tanks. The operation uses a sophisticated series of mechanical and biological filters to maintain water quality. The Acuacultura del Paraiso farm in San Luis Potosi uses 20 m diameter tanks, 2.5 m deep, to produce 9 t/mo. The tilapia produced are sold for $17/kg (US$1.70/kg) whole at the farm for retail sale in Mexico City (J. L. Aldrett Lee, pers. comm.).

Experiments in round tanks have been conducted at the Guaymas campus of ITESM and at the University of Arizona experimental facilities in Puerto Peñasco, both in Sonora. These trials focused on the potential for rearing tilapia in salt water. Both systems used a flow-through design with water returning to the ocean or, in the case of the University of Arizona, used to irrigate halophytes or seaweeds.

Figure 7. Intensively managed round tank culture.

Culture in Salt Water

One of the early introductions of tilapia to the state of Sonora was by the University of Arizona in the late 1970s. *O. mossambicus* were stocked into the discharge-settling basin of a prototype shrimp farm (Figure 8). The effluent from the farm contained elevated levels of nitrogen and phosphorus that encouraged large algae blooms. Tilapia were brought in to control the algae and provide an additional benefit for the farm staff. The fish grew quickly to harvest size in the pond, but did not reproduce in the 40–50‰ effluent water. The population was eventually completely harvested by the farm staff.

In the mid-1980s, several of the raceways and round tanks at the shrimp farm were stocked with *O. aureus, O. mossambicus* and 2 red hybrid strains. One of the red hybrids came from Taiwan and the other originated in Florida. Parental stocks were spawned at the Environmental Research Lab in Tucson, Arizona. Fingerlings were reared to 40–60 g in freshwater and then were acclimated to seawater (35%) in Tucson. Fingerlings were then transported to Puerto Peñasco and stocked into a shrimp raceway at 10 fish/m^3 with 40‰ water from a seawater well. *O. aureus* and the Taiwanese red hybrid grew slowly and eventually died. *O. mossambicus* and the Florida hybrid strain grew to 600 g in 10 mo. Some of the fish reproduced and a population has been maintained at the farm for 10 y in 40‰. The farm is now operated by GENESIS S.A.

One grow-out experiment was to stock 10 g fish in tanks with *Gracilaria*. This red algae is grown commercially as a source of agar and as a vegetable for direct human consumption. Juvenile tilapia were very effective at controlling unwanted epiphytic growth on *Gracilaria*. When the fish grew past 50 g they began to consume *Gracilaria* directly and had to be removed. By putting the algae in a sequential polyculture after a tilapia rearing tank, the *Gracilaria* was fertilized by tilapia wastes. Another multiple use

Figure 8. Shrimp and tilapia farm in Puerto Pensaco, Sonora.

of tilapia effluent was to rear tilapia in tanks or raceways and use effluent to irrigate and fertilize halophytes. Halophytes are various types of salt tolerant plants that are grown for human and animal consumption (Glenn et al. 1998).

Scientists at the ITESM have tested cages in seawater in Bahia Bocachibampo, near Guaymas, Sonora. Red tilapia were reared in cages constructed of PVC and plastic mesh in the ocean. The stocking location is a constant 35‰ salinity.

Feeds

Virtually all tilapia aquaculture in Mexico utilizes prepared feeds. In the south and in areas that use extensive culture methods, simple feeds are prepared by hand or on meat grinders from locally available materials. In the more industrialized north and urbanized areas of central Mexico, manufactured feeds are more common. Several feed companies manufacture feeds formulated specially for tilapia. Ralston Purina's subsidiary in Mexico is a major supplier. Other feed producers are malta Cleyton, Anderson-Clayton and several regional mills. Some poultry feed mills also make custom tilapia feeds.

Most of the prepared feeds are sinking feeds; however, floating feeds are also now available from some Mexican feed mills. A variety of protein levels are available, but most farms use a 32% protein formulation. These diets tend to be low in fish or animal meals, with a major portion of the protein being provided by soybean oil meal.

Markets

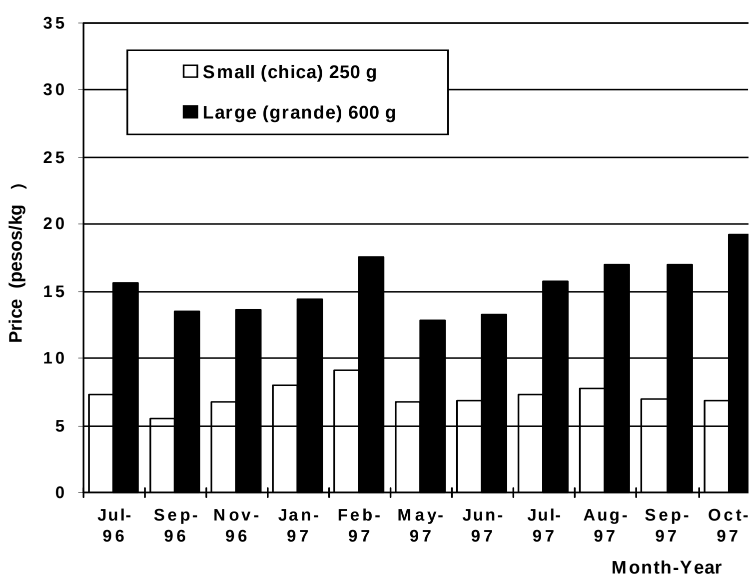
Autoconsumption

For the original producers of tilapia, markets were within the household or the local community. Early stocking programs were directed towards the rural poor and there were no marketing efforts beyond informing producers of the nutritional contribution tilapia would make to their diet. As production increased, farmers began to provide fish to local fresh markets. These marketing efforts are often organized by a cooperative of growers who band together for processing, transportation and packaging.

Local Fresh Markets

Fish sold fresh on ice are the most commonly marketed form throughout the country. Prices vary considerably during a year and in different locations around Mexico. Quality of the fish also has a tremendous impact on price. Size, presence of off-flavor and degree of freshness are key determining factors. Mexico City's retail market is the best documented (Figure 9). Large (600 g) and small (250 g) fish are available in many urban retail markets. The fish are usually provided whole on ice. For example, Mexico City prices in May of 1998 were 18 pesos/kg (0.91 US$/lb) of whole large fresh tilapia on ice,

Figure 9. Fresh whole tilapia, retail prices in Mexico City.



while small tilapia were 11 pesos/kg (0.56 US$/lb). In December of 1998 these prices had increased to 28 pesos/kg (1.27 US$/lb) and 12.5 pesos/kg (0.57 US$/lb).

Live Markets

A market for live fish has been developed in recent years. One of the cage farmers from Tamaulipas began hauling live tilapia to outlets in Guadalajara and Mexico City. He provided live tanks to stores and consumers were able to take fish home for preparation or have them prepared on the premises. He specializes in a strain of red hybrids but also has stocks of *O. aureus* and *O. niloticus*.

Another direct outlet for tilapia is on-site preparation. Many farms incorporate a small road side restaurant with their tilapia farm. Fish are harvested and prepared, often in front of the customer. The most common preparation is to gut and scale the fish and then cook it in hot oil. This is a quick, sanitary, healthy and delicious style of preparation (Figure 10).

Processing

Much of the tilapia processed in Mexico is still done by individuals harvesting their own fish or by small groups processing by hand. However, each year more fish are going to large scale processing plants with increasing amounts of value adding. Mexico has adopted Hazard Analysis at Critical Control Points (HACCP) as the new standard for processing. This applies to hand and mechanized processing of tilapia. Distribution channels are constantly improving their capability of handling tilapia product forms. This serves to increase market demand in urbanized portions of the country. It also increases the capability of exporters to supply the US, Europe and other international markets. However, exports have been quite small, considering the amount of fish grown in Mexico.

Federal and State Programs

Laws Affecting Tilapia Aquaculture

In 1990 the “Single Window” program was instituted. The intent of this program was to designate the Subsecretariat of Fisheries as the sole contact point for applicants for aquaculture permits. Rather than applying to separate agencies and boards for reviews and permits, one office would handle the entire application and contact pertinent governmental bodies. This procedure has had limited success but it can still take years to complete the process. The bulk of regulations pertaining to aquaculture in Mexico are contained in the 1992 Fisheries Law (Ley de la Pesca Reglamento 1992). It allows for 100% foreign ownership of most aquaculture operations, extended many aquaculture leases from 20–50 y, and simplified transfer and renewal of leases. Also in 1992, a new Water Law was passed. This removed many of the restrictions on use of water for aquaculture, especially opening reservoirs and irrigation canals for cage culture of tilapia.

Figure 10. Deep fried tilapia, prepared “Chiapas” style.

SEPESCA TO SEMARNAP

In December 1994, the agency that oversaw fisheries and aquaculture regulation and development, SEPESCA, was merged into SEMARNAP (Secretary of Environment, Natural Resources and Fisheries). This consolidation provided for better coordination between offices within the department which were on the one hand encouraging aquaculture development and on the other hand regulating impacts of aquaculture on natural resources. The aquaculture division within SEMARNAP has continued a "one window" policy that attempts to incorporate all permitting procedures for new aquaculture ventures into a single document (SEMAPNAP 1995).

Federal and State Hatcheries

In the past, SEPESCA was very much involved as a development agency encouraging growth of aquaculture. Low cost loan programs were available to social groups for aquaculture and government hatcheries supplied juvenile tilapia to small farms. In 1991 there were 27 SEPESCA hatcheries in 18 states producing tilapia fingerlings (Olmos Tomasini and Tejeda Salinas 1990; Aguilera Hernández and Noriega Curtis 1991b). Hatcheries would produce young tilapia that would be given to small producers and social groups. Often, fry and fingerlings would even be delivered to producers by government hatchery staff (Figure 11). The goal was to help the rural poor to improve their diet and raise their standard of living. In general this goal was achieved as many small producers grew tilapia. It has made an important contribution to household wealth and nutrition. As Mexico's economy has changed, a private sector has begun to emerge that can supply juvenile tilapia to farmers. Competition between public and private sector hatcheries, and competing fiscal priorities, has caused the government to reevaluate the goals of public hatcheries. Merging SEPESCA into SEMARNAP has accelerated this process. The agency is focusing more on regulatory and extension activities with less emphasis on social development. There is still a goal of assisting small farmers, but there are competing goals of protecting the environment and encouraging job creation and export earnings.

Application of advanced techniques for production of tilapia hybrids, selected strains and sex-reversed fingerlings has provided an opportunity for the private sector to develop a market niche. All male populations and selected strains are more expensive to produce and require sophisticated facilities and capital investments. Public sector hatcheries have historically been more involved with providing large numbers of fry for stocking programs in the rural sector. The private hatcheries supply more fry to intensive production systems. Empresa Desarrollo Acuícola Potosino, S.A. (DAPSA) is an example of a hatchery which has specialized in sex reversal of tilapia for Mexican growers. The hatchery in San Luis Potosí produces primarily sex-reversed *O. niloticus*, up to 3,000,000 fingerlings/mo, but also

Figure 11. Bagging tilapia fry for delivery to farms in Sinaloa.

has *O. aureus*, *O. mossambicus*, *O. hornorum* and their hybrids available (Rodríguez and Costero 1997). As the intensive, industrial sector has grown in importance, more hatcheries have opened to provide private sector fingerlings. SEMARNAP hatcheries have concentrated on restocking reservoirs and supplying fingerlings to social groups (*ejidos* and cooperatives) and individual farmers who operate in small ponds. However, SEMARNAP is re-evaluating all of their freshwater hatcheries, recognizing the conflict that they have with private, for-profit hatcheries.

Many Mexican states have developed their own hatcheries. Fish produced are stocked into waters of the state or provided to farmers. Like the federal hatcheries, state hatcheries are now being reevaluated as sources of tilapia. Many are dropping tilapia production in deference to private sector hatcheries and focusing instead on other species.

Diseases of Tilapia

The most common health problem encountered in Mexican tilapia is infestation with parasites. There are a number of unicellular and multicellular parasites common to most warm water fish that cause mortalities and reduced growth of cultured fish. Jimenez Guzman et al. (1988) have developed an excellent reference on parasites and diseases of tilapia. The text is a valuable reference to any tilapia farm manager or scientist.

Jimenez Guzman et al. (1988) report the most common protozoan parasite problems in Mexico are *Oodinium, Costia, Trypanosoma, Ichthiophthirius, Trichodina, Myxobolus* and *Pleistophora*. The most common multicellular parasites were trematodes (*Gyrodactylus* and *Cichlidogyrus*) and crustaceans (*Lernea, Argulus, Ergasilus* and *Lamproglena*).

The Parasitos y Enfemerdades de la Tilapia text was prepared before the emergence of *Streptococcus iniae* as a significant factor in tilapia aquaculture. The author was not aware of any *Streptococcus* infections within Mexico before the date of this publication.

SEMARNAP maintains an agreement with the Autonomous University of Nuevo Leon to provide support for fish health in Mexican aquaculture. There are plans to develop a series of regional diagnostic labs that would provide services to the industry. The source of start up funding would be from an Aquaculture Development Loan from the World Bank. Operating funds would come from a "fee" account paid by farmers submitting samples for diagnosis and for consultations on treatment and management.

Diseases appear to be only a minor constraint to producers. Most treat with salt and water exchange. The regional diagnostic labs will be tasked with providing treatment suggestions to producers under the National Aquaculture Development Plan. Scientists involved with the plan are coordinating with US and international bodies to harmonize the available treatments.

Tilapia Parks, A World Bank Project

The Government of Mexico has developed a National Aquaculture Development project in conjunction with the World Bank. The plan includes additional support for aquaculture research, training and education, environmental monitoring, HACCP training, and demonstration/development projects. A primary goal of the plan is to further develop tilapia production on a national level. In addition to more diffuse benefits to be gained from the aspects mentioned above, the plan also calls for construction and operation of 3 tilapia parks. Each tilapia park will consist of docks, a boat, and a floating cage complex. Cages would be leased to fish farmers who would care for them on an individual basis. Each complex will include 100 cages (6.5 m^3 each), central feed storage, a small water quality lab and some processing facilities. Mexican and international experts will conduct the environmental and social impact studies that are required for World Bank supported projects for each site.

The parks will be located in 3 large reservoirs in 3 states; Vicente Guerrero in Tamaulipas, El Portillo in Chiapas and Cerro de Oro in Oaxaca (World Bank 1997) (Figure 2). The intent is to support further intensification of tilapia production by large scale demonstration of the efficacy of tilapia cage culture. The parks will also be used for training of additional producers. In addition to the actual production generated from the parks, it is hoped that production will come from leaseholders who decide to expand beyond the confines of the parks into other waters.

Future

Mexico is already one of the world's major tilapia producers. With an expanding population and increasing standard of living, domestic demand is bound to increase. Proximity to the US also provides a huge potential market. Tilapia producers in Mexico are having success utilizing culture methods ranging from extensive to intensive. Low cost labor is available for low skill jobs on the farm, but at the same time Mexico has many well trained biologists who are capable of handling the most technical positions at intensively managed farms. World Bank economists predict that Mexico's tilapia production will increase to 105,780 t/y by 2005 without the tilapia parks. They expect the parks will boost that figure by another 895 t/y to 106,675 t by 2005 (World Bank 1997).

Mexico has embraced HACCP guidelines in its seafood processing industry and most processed fish already meets international standards. In spite of this, Mexican exports of tilapia to the US have been minuscule in the years 1996–1998. In fact, export amounts have decreased, reflecting the strong internal demand within Mexico (Table 3)

Table 3. Tilapia exports from Mexico to the USA. Fom National Marine Fisheries Service (1999).

Year	Form	Exports to US (kg)	Declared Value (US$)
1996	Fresh Fillets	6,617	30,631
1997	Frozen Fillets	1,223	8,723
1998	Fresh Fillets	1,057	6,626

It is anticipated that these figures will reverse by the year 2000 and exports to the US will increase. Mexico has tremendous natural and technical resources for tilapia production. Changes in exchange rates and increasing demand for tilapia products in the US will favor Mexican exports.

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